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ABSTRACT

This study compared student benefits (learning and rate of forgetting) derived from teachers being informed of the behavioral objectives and learning hierarchy of a seventh grade mathematical unit with the student benefits derived from teachers being informed of the instructional objectives of the unit in non-behavioral terms. Twenty-one seventh grade mathematics teachers were randomly assigned to one of three treatments: one group was informed of the objectives of the unit in non-behavioral terms, a second group was informed of the objectives of the same unit in behavioral terms, and the third group was informed of the behaviorally stated learning hierarchy for the unit. During eight consecutive class days each teacher taught the unit based upon the information he had received about objectives. Posttests were administered to students on the ninth day to compare the degree of learning and after four weeks to compare the rate of forgetting. Results showed no significant differences in overall achievement of the students and no significant differences in rates of forgetting. (Author/DT)

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Final Report

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LEARNING AND RATE OF FORGETTING WHEN TEACHERS ARE INFORMED OF BEHAVIORAL OBJECTIVES

December 1972

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Office of Education

National Center for Educational Research and Development
(Regional Research Program)

ABSTRACT

LEARNING AND RATE OF FORGETTING WHEN TEACHERS ARE INFORMED OF BEHAVIORAL OBJECTIVES

The results of the study do not substantiate the thesis that <u>merely informing the teachers</u> of the behavioral objectives and/or learning hierarchy of an instructional unit can enhance the performance of their students.

The study consisted of a comparison of student benefits (i.e., learning and rate of forgetting) derived from teachers being informed of the behavioral objectives and learning hierarchy of a seventh grade mathematical unit with the student benefits derived from teachers being informed of the instructional objectives of such a unit in non-behavioral terms.

Twenty-one seventh grade mathematics teachers were randomly assigned to three treatments. Teachers in one treatment group were informed of the objectives of a mathematical unit in non-behavioral terms. Teachers in a second treatment group were informed of the objectives of the same mathematical unit in behavioral terms. The teachers in a third treatment group were informed of the behaviorally stated learning hierarchy for the same mathematical unit.

Each teacher taught, during eight consecutive class days, the mathematical unit based upon the information he had received about the objectives of the unit. Posttests were administered on the ninth consecutive class day to compare the degree of learning, and, after four weeks, to compare the rate of forgetting.

The lack of differences in benefit to the students reflected in the results of the study <u>raises questions concerning</u> the increasing practice by school systems of developing and providing new teacher guides in which they <u>inform the teacher</u> of the instructional objectives in behavioral terms <u>without also providing in-service training on how to teach with behavioral objectives</u>.

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Section 1

INTRODUCTION--OBJECTIVES OF THE RESEARCH

This part of the final report states why the research was conducted. It includes a statement of the problem and related questions and a concise statement of the apparent need of the investigation.

1.1 The Problem and the Related Questions

Walbesser, Mayor, and Henkleman (1) stated in 1965 in reference to the new mathematics and science programs in secondary schools that while the decade 1955-65 had been one of curriculum innovation, the next should become one of research in learning and teaching of mathematics and science. The need and interest in classroom research for the benefit of curriculum reform has been expressed in other areas besides the area of teaching mathematics and science.

A principal goal in the curriculum-reform movements is increased learning and retention. There have been many research studies conducted to determine the effects of various manipulative variables on learning and retention. Many of these studies have contrasted the effect on achievement and retention of different classroom materials and different methods of instructing the student in the classroom. Although such efforts have been extensive, in a journal article entitled "On the Assessment of Retention Effects in Educational Experiments" Kenneth H. Wodtke (2) of the Pennsylvania State University made a plea for an even greater emphasis on long-term follow-up measures in studies of the effects of instructional treatments. He argued that there is a need for the investigation of instructional treatments specifically designed to facilitate such long-term effects. He pointed out that some instructional variations might have their primary effects on long-term retention. That is, an instructional treatment might produce relatively inefficient learning, but greater resistance to forgetting than some other treatments.

Advocates of behavioral objectives for education, such as Gagné (3), Mager (4), and Walbesser (5) have called for more specific statements of purpose and expected outcomes in new curriculum development. The American Association for the Advancement of Science has developed a curriculum entitled <u>Science--A Process Approach</u> (6), in which the objectives of the curriculum are stated in terms of what the student is to do rather than in terms of verbalizable knowledge that the student is to know. Behavioral descriptions of the objectives of curriculum has become basic to some new proposals for curriculum revision and development. Another dimension of curriculum design which has begun to play an important role in new curriculum developments is the construction of learning hierarchies. Gagné has hypothesized that intellectual skills that are learned

> . . . have an ordered relation to each other, such that subordinate ones contribute positive transfer to superordinate ones [7].

Gagné refers to learning sequences which exhibit such ordered relations between the behavioral objectives as learning hierarchies. There have been several recent researches reported which investigated the problems of hierarchy construction and behavioral description of learning outcomes. Among the contributions to this literature are those by Gagné (8,9), Walbesser (10,11,12), Walbesser and Carter (13), Engel (14), Smith (15), and Cook (16). There has been a concerted effort in some school systems to inform teachers of the instructional objectives of curriculum units in behavioral terms rather than non-behavioral terms (e.g., Baltimore County and Howard County, Maryland). Also, in some cases (e.g., Baltimore City Schools, Maryland) the teachers are being informed of the instructional objectives of curriculum units in terms of behaviorally stated learning hierarchies.

It is in the context of these three points: (1) need for long term studies, (2) need for behavioral objectives, and (3) need for learning hierarchies, that the following questions have emerged from the literature, the author's own research, and currently evolving practices in educational systems.

Q1--What effect will informing teachers of instructional objectives in behavioral terms have upon the students' (a) achievement scores, (b) over-all performance, and (c) rate of forgetting?

Q2--What effect will informing teachers of the learning hierarchy have upon the students' (a) achievement scores, (b) over-all performance, and (c) rate of forgetting?

1.2 Objectives of the Study

It was expected that the students of those teachers who have been informed of the objectives of an instructional unit in behavioral terms would attain (a) higher achievement scores, (b) higher over-all performance scores, and (c) a lower rate of forgetting than the students of those teachers who were informed of the objectives in non-behavioral terms. Moreover, it is expected that the students of those teachers who were informed of the learning hierarchy of an instructional unit would attain (a) higher achievement scores, and (b) higher over-all performance scores, and (c) a lower rate of forgetting than the students of those teachers who were informed only of the behavioral objectives of the unit.

This research study was designed to determine whether for a specific population with specific treatments data could be obtained to support the above expectations. Accordingly, seventh grade mathematics teachers in Baltimore County were randomly assigned to the three treatments (including a control treatment) delineated below. The mathematical unit in each treatment was based upon the same topical content. The first treatment listed, NB, is the control treatment.

The three treatments are defined as follows:

NB--teachers are informed of the objectives of a mathematical unit in non-behavioral terms.

B--teachers are informed of the objectives of a mathematical unit in behavioral terms.

H--teachers are informed of the learning hierarchy of a mathematical unit.

1.3 Significance of the Investigation

1.3.1 Restatement of the Question

As previously mentioned, the study investigated the effect of informing teachers of the behavioral objectives of an instructional unit and of the learning hierarchy of an instructional unit.

The results of the work by Gagné and his associates, by the Commission on Science Education of the American Association for the Advancement of Science, by the Maryland Elementary Mathematics Inservice Program (MEMIP), related research conducted by master's candidates at the University of Maryland and the author's own research seem to indicate that the following questions should be asked·

Q1--What effect will informing teachers of instructional objectives in behavioral terms have upon the students' (a) achievement scores, (b) over-all performance, and (c) rate of forgetting?

Q2--What effect will informing teachers of the learning hierarchy have upon the students' (a) achievement scores, (b) over-all performance, and (c) rate of forgetting?

1.3.2 How the Investigation Differed from Those Reported in the Literature

The literature has emphasized the need for teachers and curriculum developers to identify the behavioral objectives of instructional units in the framework of a learning hierarchy. The literature suggests that such identification aids the instructor to not only know what learned behavior he wishes the student to acquire, but also to know in what hierarchical sequence each subordinate behavior must be taught and learned in order for the next higher level behavior to be acquired by the student. In addition, the literature suggests that since the behaviors which the instructor wishes the student to acquire have been identified, he then is able to evaluate the success of the instruction by whether or not the learner has acquired the desired behaviors.

This study sought to contribute to the literature by seeking to establish the benefit to students (in terms of learning and rate of forgetting) of <u>informing the teacher</u> of the instructional objectives of the unit he is to teach in the following terms:

a. behaviorally stated objectives, and

b. behaviorally stated learning hierarchies.

While the use of such strategies finds many advocates in the literature, <u>a comparison of the benefits derived</u> from informing teachers of behavioral objectives and learning hierarchies with the benefits derived from informing teachers of non-behavioral objectives <u>has not been previously made</u>. Such a comparative study provides information for making decisions concerning the advisability of supplying teachers with behavioral objectives and learning hierarchies for units of instruction.

1.3.3 <u>How This Investigation Differed from My Study #9-C-018, Previously Funded by the Bureau of Research, U.S.O.E.</u>

The difference between this study and my earlier study is at the point of who is informed about the behavioral objectives and the learning hierarchies. In my study #9-C-018, the <u>students were informed</u> of the behavioral objectives and the learning hierarchy. Teachers were purposely deleted from study #9-C-018 so that teacher effect would not confound the results of the study. In project #9-C-018, the findings reveal that when students are informed of the behavioral objectives of an instructional unit, the rate at which the learned skills are forgotten by the students is significantly reduced. The dissemination of these findings has resulted in many teachers throughout the country making a concerted effort to make sure that their <u>students are aware</u> of an instructional unit's objectives as they study the unit.

As mentioned earlier a number of school systems are developing new teacher guides in which they <u>inform the teacher</u> of the instructional units in behavioral terms rather than in non-behavioral terms as had been the practice previously. The assumption has been made that the teacher's awareness of the behavioral objectives of a unit of instruction will improve the learning of the students. There are no previous studies which compare the difference between the student benefits derived from the teacher being informed of the behavioral objectives and learning hierarchies and the student benefits derived from the teacher being informed of only the non-behavioral objectives. The completed study made such a comparison.

Concisely, project #9-C-018 studied the benefits of informing the students of behavioral objectives and learning hierarchies while the project herein reported studied the benefits of informing the teachers of behavioral objectives and learning hierarchies.

1.3.4 Research Hypotheses Tested in the Study

From the literature it seems reasonable to expect that students will benefit from their teachers being aware of the behavioral objectives of an instructional unit. Moreover, it appears likely that students will reap an additional benefit from their teachers being informed of the hierarchical learning sequence for an instructional unit.

This research study was designed to determine whether for a specific population with specific treatments data could be obtained in support of the above expectations. Accordingly, seventh grade mathematics teachers from one school district were randomly assigned to the three treatments (including a control treatment) delineated below. The first treatment, NB, is the control treatment.

The three treatments are as follows:

NB--teachers are informed of the objectives of a mathematical unit in non-behavioral terms.

B--teachers are informed of the objectives of a mathematical unit in behavioral terms.

H--teachers are informed of the learning hierarchy of a mathematical unit.

The research hypotheses associated with the questions in Section 1.1 and which reflect the expectations in this section are:

> Research Hypothesis 1: The three treatments have differential effects upon the performance of students on an immediate posttest (achievement test).
>
> Research Hypothesis 2: The three treatments have differential effects upon the achievement scores of students of different ability levels (i.e., there is an interaction between these treatments and ability levels).
>
> Research Hypothesis 3: The three treatments have differential effects upon the over-all performance of students.
>
> Research Hypothesis 4: The three treatments result in different rates of forgetting.

1.3.5 Definition of Terms

For the purposes of this study these definitions are provided:

Manipulative variables. The written information given the teachers informing them of the behavioral objectives and the learning hierarchy of the unit of instruction; the time interval between the completion of the instructional unit and administration of the posttests.

Responding variable. The scores obtained by the students on the mathematical performance test.

Inform. The procedure of giving the teacher written statements of the behavioral objectives with appropriate examples of the tasks and/or giving to the teacher a printed copy of the learning hierarchy (with each objective written as a behavioral objective) and with appropriate examples of the tasks in the learning hierarchy.

Behavioral objective. The instructional objective of an instructional unit expressed in terms of the behavior the student is to acquire.

Terminal behavior. The behavior the learner is expected to be able to exhibit after some specified instruction and for which there are one or more behaviors the learner must acquire as prerequisites and for which there does not exist in the particular learning hierarchy a superordinate behavior.

Hypothesis of learning dependency. A one-step cumulative learning chain consisting of one terminal behavior and one or more immediate subordinate behaviors. The terminal behavior is the most complex in the chain and is dependent, in a learning sense, upon the immediate subordinate objectives. The immediate subordinate objectives are those which are necessary for the learner to acquire before he will be able to acquire the terminal objective of the chain.

Learning hierarchy. A cumulative learning sequence consisting of two or more hypotheses of learning dependency.

Rate of forgetting. The change over time in the scores made on the immediate posttest and the scores made on an equivalent posttest administered after a delay of four weeks.

Over-all performance. The score obtained when the scores on the two posttests by a student in the experiment are summed.

Section 2

RESEARCH PROCEDURE

This section presents a detailed description of the five phases of the research procedure. The first subsection deals with the experimental design. The second subsection describes the development of the treatment materials and the criterion instruments. The third subsection covers procedures used in selection and assignment of subjects. The experimental procedures are detailed in the fourth subsection and the final subsection describes the statistical designs employed in analysis of the data.

2.1 Experimental Design

One statistical design, repeated measures analysis, was used in two different ways in this study. One application sought to determine the differences in achievement between the three treatments. In the second application the differences in over-all performance and rate of forgetting between the three treatments was determined. The accompanying experimental design was of the following form:

$$
\begin{array}{llllll}
N_{NB} = 7 & R & NB^* & O_1 & O_2 \\
N_B = 7 & R & B & O_1 & O_2 \\
N_H = 7 & R & H & O_1 & O_2
\end{array}
$$

*Control treatment.

This paradigm indicates that (a) the 21 teachers were randomly assigned to three groups; (b) one group was identified as the control group and received treatment NB; (c) the second group received treatment B and a third group received treatment H; (d) an immediate posttest was administered providing observations O_1; and (e) a delayed posttest provided observations O_2.

This experimental design was selected because:

1. the design eliminated a pretest, hence the threat of the pretest being a confounding factor for the experiment was avoided; and

2. the prerequisite of random assignment would be satisfied.

2.2 Instrumentation

The two types of instruments used in this study were instructional instruments and criterion instruments. The instructional instruments consisted of the treatment materials for the experiment and included:

1. written statements of the terminal instructional objective expressed in performance terms (i.e., as a behavioral objective), and

2. behavioral objectives sequenced into a learning hierarchy with the same terminal instructional objective as in (1) above.

These materials were constructed specifically for this study. The criterion instruments included a performance test designed to measure the ability of the students to exhibit the terminal behaviors of the learning hierarchy. Two equivalent performance tests were used, one for the immediate posttest and the other for the delayed posttest. The first part of this section describes the treatment materials. The second part of the section discusses the construction of the criterion instruments.

2.2.1 Treatment Materials

The treatment materials consisted of three sheets of paper. Each treatment group received one of the three sheets of paper.

The topic. One sheet of paper contained only the words--

Instructional Unit Topic: Scientific Notation

The topic is not taught as part of the mathematics curriculum or the science curriculum in Baltimore County schools prior to January of the seventh grade.

The terminal objective: The terminal objective was selected as the result of an earlier pilot study conducted by the author and Dr. William Gray in Baltimore County public schools. In the pilot study the teachers were asked to teach the mathematical skill of changing from scientific notation to standard numeration and vice versa. The results of that investigation indicated that a more differentiating behavior should be used in the final study as the terminal instructional objective of a unit of instruction. Hence the following behavior was selected as the terminal objective for the instructional unit:

> Given two numbers expressed in scientific notation, the seventh grade mathematics student will be able to demonstrate a procedure for (a) multiplying the two numbers while expressed in scientific notation, expressing the product in scientific notation, and (b) then converting to decimal notation. Each of the two numbers given to the student will have a maximum of three significant digits. The student will not be required to round off the product.

Note that the terminal objective has two different kinds of behaviors: (a) multiplying, and (b) converting from scientific notation to decimal notation. The ability to multiply in scientific notation was the primary behavior desired while the conversion skill was considered as of secondary interest.

The learning hierarchy. A learning hierarchy consisting of the terminal behavior, its identified subordinate behaviors, and the hypothesized dependencies among these behaviors was constructed in collaboration with the chairman of a mathematics department of a junior high school in Baltimore County. The complete learning hierarchy is shown in the Appendix. The final version of the learning hierarchy used in this study was the result of modifications based upon data obtained from an earlier pilot run of the study.

2.2.2 Criterion Instruments

Construction of the two performance tests. An immediate posttest and an equivalent retention posttest were constructed to determine whether or not the students in the experiment had achieved the terminal objective of the instructional unit. Each posttest consisted of three parts; two parts (Part I and Part III) were designed to measure achievement of the terminal objective. Part III measured the more complex skill of multiplying two numbers expressed in scientific notation while Part I measured the ability to perform the simpler task of converting from scientific notation to decimal notation.

Part II was designed to measure the students' ability to convert from decimal notation to scientific notation. This part was inserted into the test for the benefit of the students and the teachers, not as a source of data for the study. It was thought that perhaps some of the students might not attain the more complex behavior of the terminal objective and the teachers might wish to have additional information which would indicate whether this lower level skill in scientific notation had been acquired by the students. This lower level skill was reflected in one of the subordinate objectives in the learning hierarchy and also is conventionally included in the topic of Scientific Notation.

Part I of each posttest had two functions: (1) to provide additional information about the students' acquisition of a subordinate behavior in the learning hierarchy, and (2) to provide data on the students' achievement of the simpler of the two behaviors in the terminal objective.

By testing behaviors (a) and (b) of the terminal objective separately, it was possible to distinguish the behaviors acquired by the students. If the data obtained from Part III showed significant differences among treatments, then the data from Part I would become important to consider. If the data from Part III revealed no significant differences among treatments, then any significant differences among treatments revealed by the data in Part I could not be utilized to draw any conclusions concerning the research hypotheses. This is because Part I would then reflect significant differences for a subordinate behavior in the learning hierarchy rather than for the terminal objective.

Each of the three parts of both the achievement posttest and the retention posttest consisted of ten problems. In each part, each of the ten problems measured the students' ability to exhibit the same kind of behavior. For example, in Part III, each of the ten problems measured the students' ability to perform the task of multiplying two numbers expressed in scientific notation. A copy of each test is included in the Appendix.

The content validity of the performance tests was assured by having three persons competent in the teaching of mathematics with behavioral objectives compare each problem with respective behavioral objective to determine whether there existed performance agreement between the test problems and the behavioral objectives. The following comparison between the terminal objective's more complex behavior and the first problem of Part III of the Achievement Posttest and the first problem of Part III of the Retention Posttest illustrates the performance agreement:

Terminal Objective (Objective 14 on the hierarchy):

> Given two numbers expressed in scientific notation, the seventh grade mathematics student will be able to demonstrate a procedure for multiplying the two numbers expressed in scientific notation, expressing the product in scientific notation, ... Each of the two numbers given to the student will have a maximum of three significant digits . . . .

Achievement Posttest:

> Part III--Multiply the following numbers and express the answer in scientific notation. Show your work.
>
> (1) $$\begin{array}{r} 2.3 \times 10^2 \\ \underline{3.1 \times 10^4} \end{array}$$

Retention Posttest:

Part III--Multiply the following numbers and express the answer in scientific notation. Show your work.

(1) 3.1×10^3
$\underline{5.8 \times 10^5}$

In order to assure equivalence between the Achievement Posttest and the Retention Posttest, care was taken to include on the two tests the same number of problems with the same number of significant figures. Again, the three persons competent in the teaching of mathematics with behavioral objectives made a comparison between the problems on the two posttests to assure that the two tests were equivalent.

The Kuder-Richardson procedure for estimating reliability was applied to the performance test scores to determine reliability of the tests under the three different treatments. The findings on test reliability are reported in a subsequent section.

2.3 Subjects

The target population chosen for this research was the set of all seventh grade mathematics teachers. The available population was the group of twenty-three seventh grade mathematics teachers in the junior high schools and middle schools of Baltimore County, Maryland, who agreed to participate in the study.

Brochures advertising for seventh grade mathematics teachers to participate in the study were delivered to the principals and mathematics department chairmen in the junior high schools and middle schools of Baltimore County. A copy of the brochure with the application form is included in the Appendix. A total of twenty-three (23) applications from seventh grade mathematics teachers in the county school system were received. Twenty-one (21) teachers were randomly selected as the sample for the project and were randomly assigned to one of three groups; a total of seven teachers in each group. A table of random numbers was utilized for the randomization process in the selection.

2.4 Experimental Procedures

On October 12, letters of acceptance were sent to those twenty-one teachers randomly selected as the sample for the project. The two remaining teachers were randomly assigned roles as alternate participants and were notified of their selection as alternates. A sample of the letter to the teachers is included in the Appendix. Teachers selected for each group were notified to attend a seminar on the campus of the University of Maryland Baltimore County according to the following schedule: Group I on October 30; Group II on November 6; and Group III on November 13.

On each of these dates the project director and a consultant, Dr. William Gray, met with the respective group of teachers. Before being given any information concerning the project, each teacher was asked to name one of their average classes of students in seventh grade mathematics. These classes were then identified by the project director as the ones to be used in the study.

Group I (the control group) was instructed on the administrative procedures of the project and then received treatment NB which consisted of being told that they were to teach the topic Scientific Notation to their students. No interpretative information about the topic was given to the teachers in Group I. Before they were informed of the topic, they were cautioned that they were not to discuss with any other participants in their group the methods they might decide to use to teach the topic. They also were instructed not to talk to any other peer teacher about what they were doing in the research project.

The seven teachers in Group II were instructed on the same administrative procedures for the project as Group I. They were then submitted to treatment B. The teachers in Group II were told of the current role of behavioral objectives in education. However, they received no instruction or other information on how to teach with behavioral objectives. The following behavioral objective was then given to them as a description of the competence that they were to teach to their students during a period of nine class days:

> Given two numbers expressed in scientific notation, the seventh grade mathematics student will be able to demonstrate a procedure for multiplying the two numbers while expressed in scientific notation, and then converting to decimal notation. Each of the two numbers given to the student will have a maximum of three significant digits. The student will not be required to round off the product.

In order to assure that interpretation of the objective was the same among the members of the group, agreement was reached concerning the type of problem that would properly measure the competence described in the objective. Each member was cautioned not to discuss his role in the project with any peer teacher and not to discuss with each other how they might decide to teach the objective.

The teachers in Group III met on the campus of UMBC on their assigned date. Like the teachers in the other groups, they were informed of the administrative procedures of the project and were cautioned not to discuss the project with anyone. This group was given a copy of a learning hierarchy containing the objective given to Group II as the terminal objective. A copy of the hierarchy is included in the Appendix. Information concerning the present role of behavioral objectives and learning hierarchies in education was given to the teachers. However, no instruction or other information on how to teach with behavioral objectives or learning hierarchies was provided the teachers. By a procedure of writing possible test items, mutual agreement was reached concerning the type of problem that was represented by the description in each objective of the hierarchy.

From November 29 to December 9, each teacher taught his previously named average class according to the information given to him in the seminar session that he attended.

On December 10, the Achievement Test was administered to the 750 students distributed among the twenty-one (21) different seventh-grade mathematics classes. Each teacher administered an Achievement Test which they had received in the mail on December 9. They had been instructed not to open the test package until the day that the test was to be administered. A copy of the Achievement Test is included in the Appendix.

Between December 10 and January 7, 1972, the tests were returned to the director, the tests were graded, and the grades returned to each teacher. Each teacher had been informed that they were not to teach any material that was related to Scientific Notation during this period. The students were not to receive any review of the material. Since the teachers were asked not to tell their students that they were involved in a research project, the teachers had permission to inform the students of the grades they made on the test. Significantly, the teachers were instructed to announce in advance the December 10 Achievement Test but not to announce the planned Retention Test scheduled for January 7, 1972.

The Retention Test scheduled for January 7, 1972, was administered to the same 750 students distributed among the twenty-one different seventh grade mathematics classes. Each of the teachers in the experiment received the Retention Test in the mail on January 6. They had been instructed, as with the Achievement Test, not to open the test package until the day that the test was to be administered. The tests were returned to the project director within a few days after they had been administered. A copy of the Retention Test is included in the Appendix.

Copies of letters of an administrative nature addressed to the teachers during this period are included in the Appendix.

2.5 Statistical Analysis

The repeated measures analysis was used in two different ways in this study. Statistical Model I was employed to determine whether the data of this study supported the first two research hypotheses, while evaluation of the data in terms of the last two research hypotheses was made using Statistical Model II.

2.5.1 Statistical Model I

Statistical Model I, an adaptation of repeated measures analysis, was used to analyze the data obtained in the study to determine whether the data supported these two research hypotheses:

Research Hypothesis 1: The three treatments have differential effects upon the performance of students on an immediate posttest (achievement test).

Research Hypothesis 2: The three treatments have differential effects upon the achievement scores of students of different ability levels (i.e., there is an interaction between these treatments and ability levels).

It is often suggested that a proper unit of analysis in classroom research is the class mean. Information concerning individual differences is lost in the analysis by reducing the diversity within any class to an average score. Page (17) has advocated that the richness of the classroom research may be re-captured by treating sub-categories found within a classroom (e.g., levels of ability) as if they represented repeated measurements on the same subject under different pseudo-conditions. De Sena and Weber (18) have shown a high positive correlation between grades and achievement. Accordingly, the students in each of the classrooms of the twenty-one teachers were divided into subgroups of high, middle, and low ability by the grades they received in the prior reporting period. The resulting grade levels were designated High for a grade of A, Medium for a B, and Low for either a C or D.

Hence, the following experimental design shown in Table 1 was used to determine differences in achievement between the three treatments NB, B, and H. The twenty-one teachers randomly assigned to the three treatments are designated T_1, T_2, T_3, T_4, ..., T_{21}. The levels of ability are treated as repeated measures. The datum entered into a particular position in the schematic shown in Table 1 (see X for example) will be the mean score of the specific level students under a particular teacher subjected to a particular treatment.

Table 1

Schematic of Statistical Model I

		Ability Levels		
		Low	Middle	High
	T_1	X		
	T_2			
Treatment NB	⋮			
	T_7			
	T_8			
	T_9			
Treatment B	⋮			
	T_{14}			
	T_{15}			
	T_{16}			
Treatment H	⋮			
	T_{21}			

Congruence between the experimental design of this study and the planned statistical analysis of the data with this application of the repeated measures analysis was sought by the decision to follow the schema suggested by Hopkins and Chadbourn (19) and Hays (20) for making c multiple comparisons among k treatments. Based upon experimental conditions of this study and the Hopkins and Chadbourn schema, the Scheffe analysis was included in the statistical design as the technique for locating significant differences between treatment means. In addition, the statistical design included the plotting of the treatment-by-levels interaction profiles as a technique for obtaining an indication of the relative effects within ability levels resulting from the three treatments. These profiles consist of graphically depicted data showing changes in achievement scores across ability levels separated by treatment methods.

The <u>assumptions</u> for this statistical analysis are:

1. The teachers were randomly assigned to treatments.

2. The variances of the teacher means within the three treatments are homogeneous.

3. The variance of the "interaction of levels and teachers within treatments" is a pooling of the variance of the scores in each treatment group about the treatment mean after the effects of levels and the effects of teachers within treatments have been subtracted out. These variances for each treatment group are homogeneous.

4. The scores collected are normally distributed (from a normal population).

The randomization assumption was met in the manner discussed in Section 2.3.

Homogeneity of variances was tested by the F_{max} test. The findings are included in Section 3.

Ferguson had this to say concerning the robustness of the assumption of normality:

> For large samples the normality of the distributions may be tested using a test of goodness of fit, although in practice this is rarely done. When the samples are fairly small, it is usually not possible to rigorously demonstrate lack of normality in the data. Unless there is reason to suspect a fairly extreme departure from normality, it is probable that the conclusions drawn from the data using an F test will not be seriously affected [21].

All of the teachers in the target population were seventh grade mathematics teachers. All of the teachers in the available population were seventh grade teachers in the junior high schools and the middle schools of Baltimore

County, Maryland. The students whom the teachers' taught were in their average seventh grade classes. The assumption was made that the population from which the teachers were obtained was normal with respect to ability as teachers and the students in their classes were normal with respect to their ability as students.

The decision was made before the analysis of the data to set the maximum probability of making a type-I error (α) at .05.

An experiment-wise error rate was chosen because it was considered desirable to be able to state in all of the comparisons in this experimental study there was only an $\alpha = .05$ probability that a type-I error was made. Choosing an error rate that was experiment-wise meant that regardless of the number of permissible comparisons carried out, the probability was no more than .05 that one or more of the comparisons will turn out to be spuriously significant.

2.5.2 Statistical Model II

Statistical Model II consists of the repeated measures analysis. This analysis procedure was used to analyze the data obtained in the study to determine whether the data supported these two research hypotheses:

> Research Hypothesis 3: The three treatments have differential effects upon the over-all performance of students.
>
> Research Hypothesis 4: The three treatments result in different rates of forgetting.

Wodtke (22) states that the repeated measures design, described by Grant (23) and Winer (24) seems most appropriate for the study of differential rates of forgetting. Retention in this study has been defined as the number of learned behaviors that are retained over a four-week interval. Therefore, the repeated measures analysis was utilized in Statistical Model II to determine differences in over-all performance and rate of forgetting between the three treatments.

Two posttests are to be given. One will be given immediately after completion of the study unit, while the second posttest will be a Retention Test given four weeks later. The immediate Achievement Test and the Retention Test will consist of identical test items listed in different order. A schematic representation of the design is shown in Table 2.

Table 2

Schematic of Repeated Measures Analysis Design

		Posttests	
		Immediate	Delayed
Treatment NB	T_1	X	
	T_2		
	⋮		
	T_7		
Treatment B	T_8		
	T_9		
	⋮		
	T_{14}		
Treatment H	T_{15}		
	T_{16}		
	⋮		
	T_{21}		

The datum entered into a particular position (see X for example) will be the mean score of students for a specific posttest under a specific teacher who was subjected to a specific treatment.

Wodtke explains that a statistically significant over-all effect (i.e., summer effect of the immediate and the retention tests) between treatments

> . . . would indicate that one instructional treatment was generally superior to another. A statistically significant treatment-by-retention measures interaction would indicate that the slopes of the retention curves in the treatment groups differed [25].

Based upon experimental conditions of this study and Hopkins and Chadbourn schema mentioned in Section 2.5.1, the Tukey-b method described by Winer (26) was included in the statistical design as the technique for locating significant differences between over-all performance means. In addition, the statistical design included the plotting of the slopes of the retention curves as a technique for determining which treatments resulted in the least rate of forgetting (i.e., improved retention).

The <u>assumptions</u> made for this repeated measure analysis are:

1. The teachers were randomly assigned to the treatments.
2. The variances of the teacher means within the various treatments are homogeneous.
3. The variance of the "interaction of posttests and teachers within treatments" is a pooling of the variance of the scores in each treatment group about the treatment mean after the effects of posttests and the effects of teachers within treatments have been subtracted. These variances for each treatment group are homogeneous.
4. The scores collected as data are normally distributed.

The assumptions of homogeneity of variance were tested by the F_{max} test. The findings are included in Section 3.

Section 3

FINDINGS

The findings reported in this section in two subsections are related to the following topics:

a. the reliability of the posttests, and

b. the data analysis relevant to the four research hypotheses stated in Section 2.

The second subsection is divided into two parts. The findings related to the comparison of the effects of the three treatments upon achievement scores are reported in the first part entitled Achievement Analysis. In the second part of the second subsection, entitled Repeated Measures Analysis, the findings pertaining to the comparison of the effects of the three treatments upon over-all performance and rate of forgetting are reported.

In the second subsection, the research hypotheses are restated preceding the null hypotheses tested. After the relevant findings are reported, a statement of the appropriate statistical decision concludes each presentation.

3.1 Criterion Instrument Reliability

The Kuder-Richardson procedure for estimating reliability, using test-item statistics, was applied to the Achievement Test scores of the sample used in the study. The Kuder-Richardson formula 21 measures internal consistency or homogeneity of the test. An estimate of the reliability of the test under Treatment NB and Treatment H is provided by the reliability coefficients of .62 and .88, respectively.

In his discussion related to analysis and evaluation of science tests, Hedges provides an answer to the question concerning an acceptable value for the reliability of science tests. Hedges (27) states,

> Your own tests should have a reliability of about .60, whereas standardized test-makers should get as high as .90 or more.

He also adds,

> If you ever get as high as .67 on one of your tests be grateful.

On the basis of the criteria suggested by Hedges, the reliability coefficients obtained provide sufficient evidence to support the assumption of the reliability of the posttest.

3.2 <u>Comparison of Experimental Treatments</u>

Statistical procedures utilized in this study to compare the effects of the three treatments on learning and rate of forgetting include two applications of repeated measures analysis. The first application considered in this subsection treats the ability levels of students as repeated measures in an analysis of the achievement scores.

3.2.1 <u>Achievement Analysis</u>

The comparative effectiveness of the three treatments on student achievement was studied by treating ability levels of students as if they represented repeated measurements on the same subject under different pseudo-conditions. The findings relative to achievement pertain to the first two hypotheses.

> <u>Research Hypothesis 1</u>: The three treatments have differential effects upon the performance of students on an immediate posttest (achievement test).

This hypothesis was examined by testing the statistical null hypothesis:

$$H_o^1: \alpha_k = 0, \quad \text{for all } k$$

Where α_k = the effect of being in the k^{th} treatment group.

Research Hypothesis 2: The three treatments have differential effects upon the achievement scores of students of different ability levels (i.e., there is an interaction between these treatments and ability levels).

This hypothesis was examined by testing the statistical null hypothesis:

$$H_o^2: \alpha\gamma_{jk} = 0, \quad \text{for all ik}$$

Where $\alpha\gamma_{jk}$ = the interaction of the j^{th} ability level and the k^{th} treatment.

A summary of the results of the analysis of the immediate posttest scores appears in Table 3. The F ratio observed for treatment effect was 0.31. The critical value of F at 2,18 df and 0.05 level of significance is 3.55. Hence, the null hypothesis

$$H_o^1: \alpha_k = 0, \quad \text{for all } k$$

was retained. The F ratio for treatment-by-levels interaction effect was 0.75. Since the critical value of F at 4,36 df and 0.05 level of significance is 2.64, the null hypothesis

$$H_o^2: \alpha\gamma_{jk} = 0, \quad \text{for all } jk$$

was retained. No data were analyzed using the Scheffe analysis.

Since both null hypotheses were retained, no analysis of the data obtained from Part I of the Achievement Test was made.

Table 3

Summary of Achievement Analysis Utilizing Statistical Model I

Source of Variation	df	SS	MS	F	F at .05
Between Teachers	20				
Between Treatments	2	676.09	338.05	--	
Teachers within Treatments . .	18	19836.76	1102.04	.31 ns	3.55
Within Teachers	42				
Levels	2	11253.71	5626.86	--	
Treatment x Levels	4	780.19	195.05	.75 ns	2.64
Levels x Teachers within Tr. .	36	9302.10	258.39		
Total	62	41848.86			

*Significant at the .05 level of significance.

The marginal standard deviations and the cell and marginal means of the three treatment groups on the immediate posttest (Achievement Test) are reported in Table 4.

Table 4

Means, Cell Sizes, and Standard Deviations of Levels of Ability Scores on Achievement Test

	Levels of Ability			
Treatments	Low	Medium	High	
NB	$\bar{X}_{NB1} = 38.9$ $n_{NB1} = 7$	$\bar{X}_{NB2} = 59.0$ $n_{NB2} = 7$	$\bar{X}_{NB3} = 70.1$ $n_{NB3} = 7$	$\bar{X}_{NB.} = 56.0$ $SD_{NB.} = 23.8$
B	$\bar{X}_{B1} = 45.6$ $n_{B1} = 7$	62.5 7	69.0 7	$\bar{X}_{B.} = 59.0$ $SD_{B.} = 19.1$
H	42.9 7	61.8 7	84.5 7	$\bar{X}_{H.} = 63.1$ $SD_{H.} = 33.6$
	$\bar{X}_{.1} = 42.5$ $SD_{.1} = 21.2$	$\bar{X}_{.2} = 61.1$ $SD_{.2} = 27.4$	$\bar{X}_{.3} = 74.5$ $SD_{.3} = 18.2$	$\bar{X}_{T} = 59.4$

The F_{max} test was used to test the degree of homogeneity of the variances of the teacher means within the three treatments. The F_{max} observed was 2.72 and the F_{max} critical was 4.28 with 6,6 df at 0.05 level of significance. Hence, the homogeneity of variances of the teacher means within the three treatments was supported by the data.

The F_{max} test was also used to test the degree of homogeneity of the levels x teachers within treatments variances. The F_{max} observed was 3.40 and the F_{max} critical was 2.69 with 12,12 df at 0.05 level of significance.

This finding does not support the assumption that the variances of the interaction of levels and teachers within treatments are homogeneous. However, the classical study by Norton (28) of the effects of heterogeneity of variance provides support for stating that this assumption of homogeneity is not crucial to this adaptation of the repeated measures analysis procedure. Norton found that the analysis of variance test was robust with regard to violations of the homogeneity of variance assumption. Ferguson (29), also, argued for the robustness of the analysis of variance test to departures from the homogeneity assumption. The robustness in regard to homogeneity assumption also applies to the adaptation of the repeated measures analysis procedure used in this study.

3.2.2 Repeated Measures Analysis

The effectiveness of the three treatments on student over-all performance and rate of forgetting was studied using a repeated measures analysis. The findings relative to over-all performance and rate of forgetting pertain to the last two research hypotheses.

> Research Hypothesis 3: The three treatments have differential effects upon the over-all performance of students.

This hypothesis was examined by testing the statistical null hypothesis:

$$H_o^3: \alpha_k = 0, \quad \text{for all } k$$

Where α_k = the effect of being in the k^{th} treatment group.

> Research Hypothesis 4: The three treatments result in different rates of forgetting.

This hypothesis was examined by testing the statistical null hypothesis:

$$H_o^4: \alpha\gamma_{ik} = 0, \quad \text{for all } ik$$

Where $\alpha\gamma_{ik}$ = the interaction i^{th} posttest and the k^{th} treatment.

A summary of the results of the repeated measures analysis of immediate and delayed posttests appears in Table 5. The F ratio observed for treatment effect was 0.21. The critical value of F at 2,18 df and 0.05 level of significance is 3.55. Hence, the null hypothesis

$$H_o^3: \alpha_k = 0, \quad \text{for all } k$$

was retained. The F ratio observed for treatment-by-posttest interaction effect was 1.71. Since the critical value of F at 2,18 df and 0.05 level of significance is 3.55, the null hypothesis

$$H_o^4: \alpha\gamma_{ik} = 0, \quad \text{for all } ik$$

was also retained. No data were analyzed using the Tukey-b analysis.

Since both null hypotheses were retained, no analysis of the data obtained from Part I of the Achievement Test and from Part I of the Retention Test was made. Also because both null hypotheses were retained, neither the treatment-by-levels interaction profiles nor the treatment-by-posttest interaction profiles (retention curves) were plotted. The profiles were to provide, respectively, indication of the relative effects within ability levels and a determination of which treatment resulted in the least rate of forgetting.

The marginal standard deviations and the cell and marginal means for the immediate posttest (Achievement Test) and the delayed posttest (Retention Test) scores in the repeated measures analysis is presented in Table 6. The F_{max} test was used to test the degree of homogeneity of the variances. The F_{max} observed was 5.20 and the F_{max} critical was 4.28 with 6,6 df at 0.05 level of significance. The discussion on page 29 concerning the robustness of the analysis of variance in regard to the assumption of homogeneity of variances applies in this case, also.

3.3 Summary of Findings

A comparison of the three treatment means of the immediate posttest (Achievement Test) detected no significant difference at the 0.05 level of significance. Also, an

Table 5

Summary of Repeated Measures Analysis

Source of Variation	df	SS	MS	F	F at .05
<u>Between Teachers</u>	20				
Between Treatments	2	299.19	149.60	--	
Teachers within Treatments . .	18	12914.71	717.48	.21 ns	3.55
<u>Within Teachers</u>	21				
Posttests	1	1920.38	1920.38	--	
Treatment x Posttests	2	306.05	153.02	1.71 ns	3.55
Posttests x Teachers within Treatments	18	1613.57	89.64		
Total	41	41848.86			

*Significant at the .05 level of significance.

Table 6

Means, Cell Sizes, and Standard Deviations of Immediate and Delayed Posttest Scores

Treatments	Posttests: Immediate	Posttests: Delayed	
NB	$\bar{X}_{NB1} = 47.9$ $n_{NB1} = 7$	$\bar{X}_{NB2} = 38.6$ $n_{NB2} = 7$	$\bar{X}_{NB.} = 43.3$ $SD_{NB.} = 16.8$
B	$\bar{X}_{B1} = 51.2$ $n_{B1} = 7$	$\bar{X}_{B2} = 30.0$ $n_{B2} = 7$	$\bar{X}_{B.} = 40.6$ $SD_{B.} = 18.1$
H	$\bar{X}_{H1} = 52.2$ $n_{H1} = 7$	$\bar{X}_{H2} = 42.0$ $n_{H2} = 7$	$\bar{X}_{H.} = 47.1$ $SD_{H.} = 26.1$
	$\bar{X}_{.1} = 50.4$ $SD_{.1} = 20.6$	$\bar{X}_{.2} = 36.9$ $SD_{.2} = 18.2$	$\bar{X}_{T} = 43.7$

analysis of the immediate achievement scores did not yield a significant interaction between treatments and levels of ability.

No significant differences were found between the over-all performance means of the three treatments. Also, no significant difference in rate of forgetting resulting from the three treatments was observed.

Section 4

CONCLUSIONS

The conclusions based upon the findings yielded by statistical treatment of the data are presented below. Each conclusion is stated in terms of the relevant research hypothesis.

1. The hypothesis that informing teachers of the behavioral objectives or learning hierarchies of a unit of instruction has a differential effect upon the achievement scores of their students as compared to informing the teachers of the instructional objective in non-performance terms is not supported by the data.

2. The hypothesis that informing teachers of the behavioral objectives or learning hierarchies as compared to informing them of the instructional objective in non-performance terms has differential effects upon the achievement scores of students of different ability levels is not supported by the data.

3. The hypothesis that the three treatments have differential effects on the over-all performance of students is not supported by the data.

4. The hypothesis that the three treatments result in different rates of forgetting is not supported by the data.

Section 5

IMPLICATIONS AND RECOMMENDATIONS

The results of the study appear to be quite conclusive in terms of there being no observable differential effects of the three treatments on immediate test scores. The analysis of the data provided no support for qualifying this finding on the basis of ability levels.

The results of the study also indicate that the benefits in terms of over-all performance to be derived from either of the three treatments do not differ significantly at the 0.05 level. Similar results of the study in terms of rate of forgetting were obtained. The benefits to the student, in terms of rate of forgetting, to be derived from either of the three treatments are not significantly different.

The implications derived from the findings of this study pertain to current practice and future research.

5.1 Implications for Current Practice

a. The findings of this study lend no support to the assertion that _merely_ telling the teacher the behavioral objective and/or learning hierarchy of a unit of instruction will increase the performance of his students on immediate achievement tests.

b. The increasingly current practice of translating instructional objectives into behavioral objectives for inclusion in teachers' guide books _without training the teachers how to teach with behavioral objectives_ can not be expected to be of benefit to the students in terms of learning and rate of forgetting.

c. Hence, the practice of legislating teacher accountability and the providing of funds for identifying behavioral objectives will not yield the desired benefits to the students unless school systems make major efforts to re-train their teachers via in-service programs to teach effectively with the behavioral objectives that have been identified.

5.2 Recommendations for Future Research

The results of this study have indicated it is not beneficial to the students in terms of learning and rate of forgetting for the teacher to be merely told what the behavioral objectives are and/or how the objectives can be sequenced into a learning hierarchy. It is recommended that a study be made in which teachers are randomly assigned to three different treatments which go beyond the treatments provided in this study. The new study would consist of a control group of teachers who would teach after being informed of the behavioral objective of an instructional unit. The teachers in the control group would not be shown how to teach with behavioral objectives.

The second treatment group would be trained to teach with behavioral objectives in such a manner that would assure performance agreement between the instructional objectives, the teaching strategies, and the evaluation of student achievement. This instructional system would then be applied in their classrooms.

The third treatment group would receive the same training as the second treatment group, but, in addition, the third treatment group would be trained to utilize a learning hierarchy to assure the continued progress of their students. This managerial skill would reflect the role of the teacher as a facilitator of learning: a diagnostician, a prescriber, and an enabler. This application of the learning hierarchy would then be applied in their classrooms.

The differential effect in terms of achievement, over-all performance, and rate of forgetting would then be analyzed.

APPENDIX

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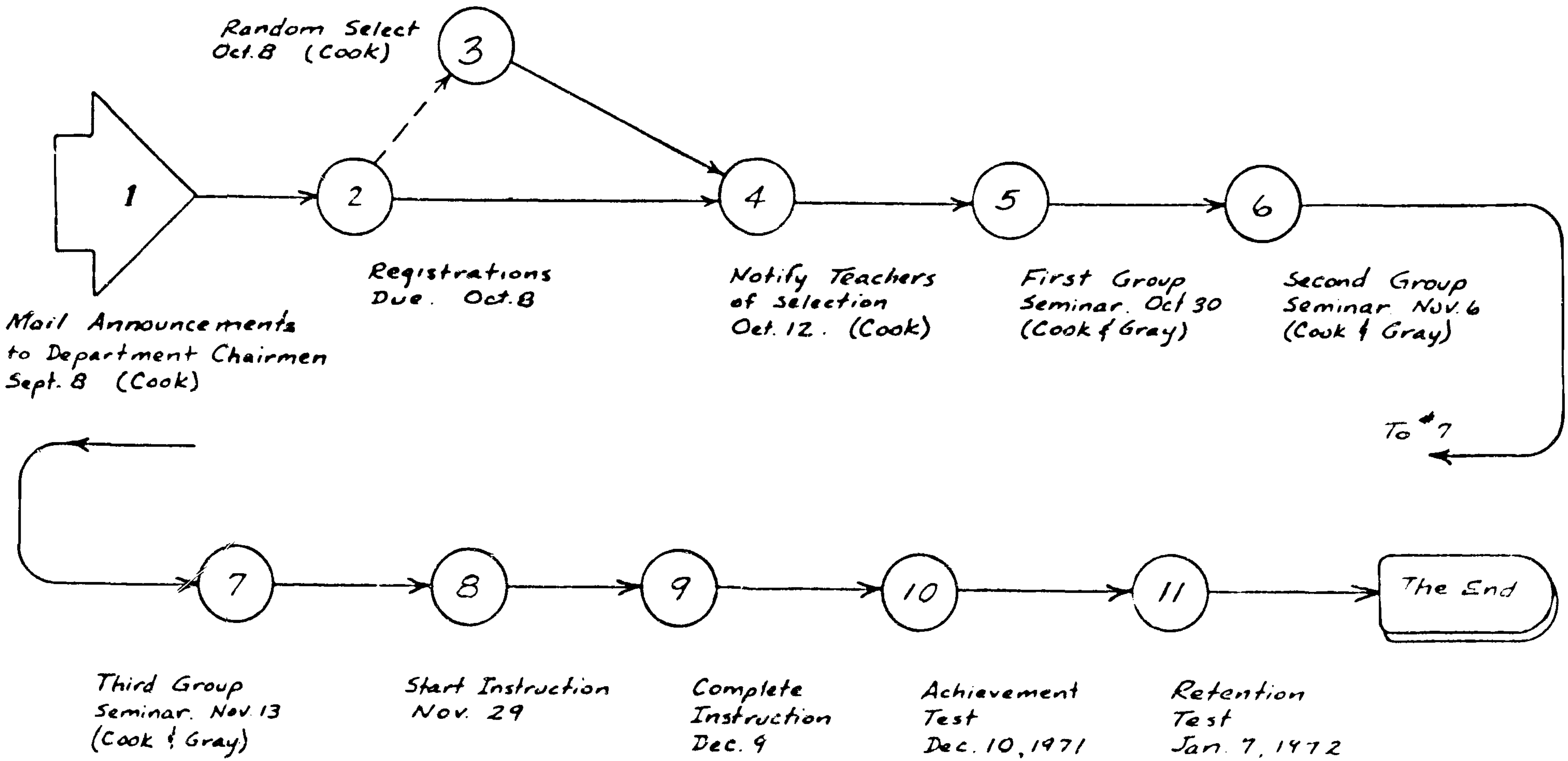
PERT NETWORK

FOR UMBC and BALTIMORE COUNTY MATH RESEARCH PROJECT



J. Marvin Cook
PROJECT DIRECTOR

WANTED

SEVENTH GRADE MATHEMATICS TEACHERS

Dr. J. Marvin Cook, Associate Professor of Education, University of Maryland Baltimore County, is conducting a research project on teaching methods in seventh grade mathematics during November and December, 1971. He will need twenty-one seventh grade mathematics teachers from Baltimore County to participate in the study. Each teacher participating in the study will attend a seminar to be held on one of the following Saturdays: October 30, November 6, or November 13, 1971. An honorarium of $50.00 will be paid to each teacher participating in the study. Using the teacher method discussed in the seminar, each teacher will teach specific seventh grade mathematics material during consecutive class days in his own classroom. On the last class day, each teacher will administer a test prepared for the study. A second administration of the test will be made one month later. No outside observer will be present during the consecutive class days.

Dr. William Gray, Chairman of the Mathematics Department, Arbutus Junior High School, will serve as consultant for the study, which has been approved by the Office of Mathematics.

If you wish to participate in the research project, mail the application to Dr. Cook by October 8, 1971. Twenty-one teachers will be selected randomly by Dr. Cook from the applicants for participation in the project. Each applicant will be notified of the outcome of the random selection by October 12, 1971.

- - - - - - - - - - - - - - - - Detach here - - - - - - - - - - - - - - - -

ENROLLMENT FORM
University of Maryland Baltimore County Research Project
Teaching Methods in Seventh Grade Mathematics
Dr. J. Marvin Cook, Director

Name ______________________________ Date ______________

Telephone ______________ Social Security Number ______________

Address ____
(No. and Street) (City) (State) (Zip)

Send form to: Dr. J. Marvin Cook
University of Maryland Baltimore County
5401 Wilkens Avenue
Baltimore, Maryland 21228

UNIVERSITY OF MARYLAND
BALTIMORE COUNTY

UMBC

5401 Wilkens Avenue · Baltimore, Maryland 21228

Division of Education

October 22, 1971

M's Sue M. Pearson
7323 Berkshire Road
Baltimore, Maryland 21224

Dear M's Pearson:

You have been selected as a participant in the University of Maryland Baltimore County research project on teaching methods in seventh grade mathematics. The brochure you received earlier describing the project mentioned that each randomly selected particpant would attend a seminar in preparation for his role in the study. Using the teaching method discussed in the seminar, each teacher will teach specific seventh grade mathematics material during consecutive class days in his own classroom. On the last consecutive day, each teacher will administer a test prepared for the study. A second administration of the test will be made one month later.

The seminar for the project will be held on the UMBC campus, on Saturday, October 30, 1971, from 9:45 a.m. - 11:00 a.m. We will meet in the Education-Mathematics Building, in room #301. The details of the project will be outlined at that time. A map of the UMBC campus is enclosed for your convenience. On the map, the building is designated as Faculty-Office-Classroom Building, #6.

Dr. William Gray and I look forward to working with you on this project. If questions arise, please contact me at 455-2306 on the UMBC campus.

Sincerely,

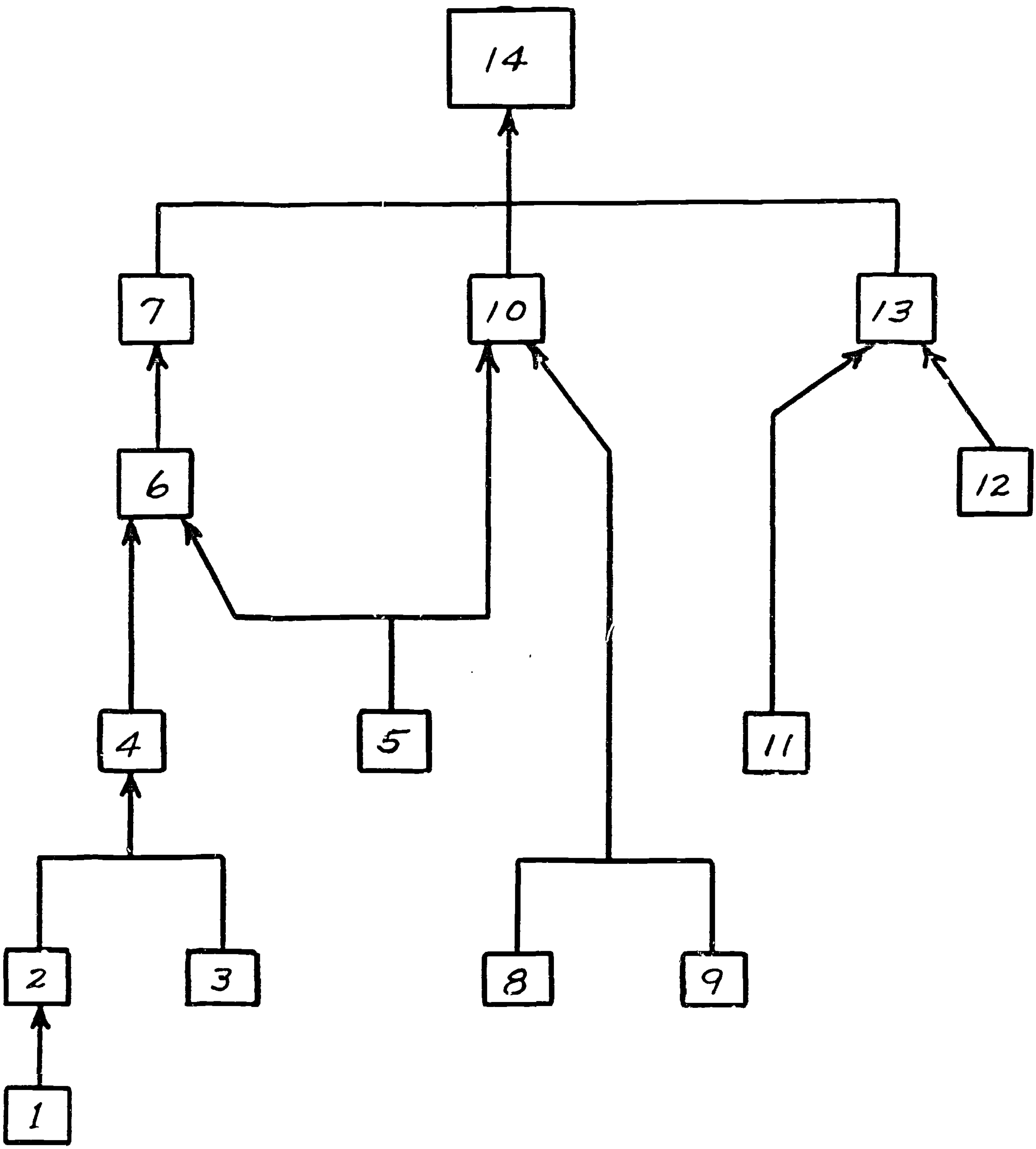
J. Marvin Cook

J. Marvin Cook
Associate Professor

jmc/dgp

enc.

LEARNING HIERARCHY



OBJECTIVES

Note: In each objective stated below, the term "student" refers to the seventh grade math student.

Definition: A <u>power of ten number</u> or a <u>power of ten</u> to be a whole number in decimal form which could be expressed exponentially as ten raised to some power greater than or equal to one.

Examples: 10
10,000
1,000,000

In this study the power of ten number will have a maximum of <u>twelve digits</u>.

1. Given a number as a dividend with a maximum of six digits expressed in decimal form, the student will be able to apply a rule for dividing the number by a given power of ten. The divisor will have the same or less than the number of digits to the left of the decimal point as the dividend.

2. Given a whole number expressed in decimal form with a maximum of six digits, the student will be able to apply a rule for naming the number as the product of a decimal number between one and ten and a power of ten.

3. Given a power of ten number, the student will be able to apply a rule for expressing the power of ten number exponentially.

4. Given a whole number expressed in decimal form with a maximum of six significant digits, the student will be able to apply a rule for naming the number as the product of a decimal number between one and ten and a power of ten expressed exponentially.

5. Given a list of numbers which are in the form of the products of decimal numbers and powers of ten expressed exponentially, the student will be able to distinguish those numbers in the list which are expressed in scientific notation.

6. Given numbers in decimal notation, the 7th grade math student will be able to express those numbers in scientific notation. The numbers given to the student in decimal notation will be whole numbers with a maximum of six significant digits.

7. Given numbers in decimal notation, the 7th grade student will be able to express those numbers in scientific notation. The numbers given to the student in decimal notation will each have a maximum of six digits with the decimal point immediately to the right of any of the six digits.

8. Given a number expressed in decimal form, the student will be able to apply a rule for multiplying the given number by a given power of ten. The given multiplicand will have a maximum of six digits with the decimal point immediately to the right of any of the digits.

9. Given a power of ten expressed exponentially, the student will be able to apply a rule for expressing the given number as a decimal number.

10. Given numbers expressed in scientific notation, the 7th grade math student will be able to express those numbers in decimal notation. The numbers given to the student in scientific notation will have powers of ten equal to or less than eleven and a maximum of six significant digits.

11. Given two numbers from one (1) to ten (10) expressed decimally, the student will be able to construct the product of these two numbers. Each of the two numbers will have a maximum of three significant digits. They will not necessarily have the same number of digits.

12. Given two powers of ten expressed exponentially, the student will be able to construct the product of these numbers by adding the expondents.

13. Given two numbers expressed in scientific notation, the student will be able to apply the rule (algorithm) for multiplying the numbers. The sum of the two exponents will not exceed ten.

14. Given two numbers expressed in scientific notation, the seventh grade mathematics student will be able to demonstrate a procedure for multiplying the two numbers while expressed in scientific notation, expressing the product in scientific notation, and then converting to decimal notation. Each of the two numbers given to the student will have a maximum of three significant digits. The student will not be required to round off the product.

UMBC

UNIVERSITY OF MARYLAND
BALTIMORE COUNTY

5401 Wilkens Avenue · Baltimore, Maryland 21228

Division of Education

November 24, 1971

Dear Participant:

In order for you to be paid before Christmas, please fill in the enclosed forms and return them immediately to Dr. William Gray, Arbutus Junior High School. These forms must be received by Wednesday, December 1, in order for payment to be processed in time for Christmas.

Sincerely,

J. Marvin Cook

J. Marvin Cook
Associate Professor

jmc/dgp

UNIVERSITY OF MARYLAND
BALTIMORE COUNTY

UMBC

5401 Wilkens Avenue · Baltimore, Maryland 21228

Division of Education

December 6, 1971

Dear Research Participant:

Please administer the test and return the test forms (retaining enough forms for students who are absent) immediately to Dr. William Gray, Chairman of the Math Department, Arbutus Junior High School. The students should do all their work on the test forms. Allow sufficient time for all students to finish.

Please do not forget to return a class list with the students' previous six-weeks math grade. Also, please let us know which students missed more than one class during the instruction period.

When an absent student makes up the test, please return his test immediately to Dr. Gray. Remember that the students are not to be told that there will be a retention test later. Again, let me express our appreciation for your cooperation in this project.

Sincerely,

Dr. J. Marvin Cook

jmc/dgp

NAME ______________________ DATE ______________

SCIENTIFIC NOTATION
ACHIEVEMENT TEST

Part I - In the space provided, change from scientific notation to decimal notation.

(1) 2.13×10^4 = ______________

(2) 3.6×10^2 = ______________

(3) 5.73×10^7 = ______________

(4) 2.4513×10^8 = ______________

(5) 7.1×10^1 = ______________

(6) 3.14×10^7 = ______________

(7) 2.54×10^6 = ______________

(8) 3.6×10^9 = ______________

(9) 9.14×10^{11} = ______________

(10) 3.51×10^{10} = ______________

Part II - In the space provided, change from decimal notation to scientific notation.

(1) 64,000 = ______________

(2) 5,200,000 = ______________

(3) 35,000,000,000 = ______________

(4) 2,510 = ______________

(5) 3,710,000 = ______________

(6) 50,000 = ______________

(7) 370,000 = ______________

(8) 919,000,000 = ______________

(9) 7,145,000 = ______________

(10) 82,000,000 = ______________

NAME________________________

Part III - Multiply the following numbers and express the answer in scientific notation. Show your work.

(1) 2.3×10^2
$\underline{3.1 \times 10^4}$

(2) 5.8×10^7
$\underline{4.1 \times 10^6}$

(3) 7.13×10^7
$\underline{2.1 \times 10^3}$

(4) 4.9×10^3
$\underline{3.7 \times 10^3}$

(5) 9.3×10^8
$\underline{3.9 \times 10^1}$

(6) 1.1×10^7
$\underline{2.2 \times 10^3}$

(7) 3.142×10^1
$\underline{1.7 \times 10^5}$

(8) 1.12×10^3
$\underline{2.3 \times 10^5}$

(9) 9.1×10^7
$\underline{3.2 \times 10^6}$

(10) 7.172×10^6
$\underline{1.6 \times 10^3}$

UNIVERSITY OF MARYLAND
BALTIMORE COUNTY

5401 Wilkens Avenue · Baltimore, Maryland 21228

UMBC

Division of Education

December 21, 1971

Dear Research Participant:

Your test papers are being graded and the results hopefully will be included with this letter. You should have them when you return to school after Christmas.

I'd like to remind you that the retention test is scheduled for Friday, January 7. Your test packages will be placed in the inter-office mail on Monday, January 3. Even though you may receive the tests early, please don't administer them until January 7. The students should not expect the test! Again, please do not review any of the material for the test.

Dr. Gray and I wish you a very Merry Christmas and a New Year that brings real happiness to you and yours.

Sincerely,

Dr. J. Marvin Cook

jmc/dgp

UNIVERSITY OF MARYLAND
BALTIMORE COUNTY

UMBC

5401 Wilkens Avenue · Baltimore, Maryland 21228

Division of Education

January 3, 1972

Dear Research Participant:

Please administer the retention test on Friday, January 7, and return the test forms (retaining enough forms for students who are absent) immediately to Dr. William Gray, Chairman of the Math Department, Arbutus Junior High School. The students should do all their work on the test forms. Allow sufficient time for all students to finish. Please assure that the retention test is "taken seriously" by the students.

When an absent student makes up the test, please return his test immediately to Dr. Gray. Again, let me express our appreciation for your cooperation in this project. A letter is forthcoming in which the entire project will be described to you.

Sincerely,

J. Marvin Cook

Dr. J. Marvin Cook

jmc/dgp

NAME ______________________ DATE ______________________

SCIENTIFIC NOTATION
RETENTION TEST

Part I - In the space provided, change from scientific notation to decimal notation.

(1) 7.28×10^5 = ____________________

(2) 4.3×10^4 = ____________________

(3) 2.53×10^6 = ____________________

(4) 5.3541×10^7 = ____________________

(5) 6.7×10^2 = ____________________

(6) 2.51×10^6 = ____________________

(7) 2.64×10^{11} = ____________________

(8) 4.7×10^1 = ____________________

(9) 8.69×10^{10} = ____________________

(10) 6.58×10^9 = ____________________

Part II - In the space provided, change from decimal notation to scientific notation.

(1) 45,000 = ____________________

(2) 7,300,000 = ____________________

(3) 18,000,000,000 = ____________________

(4) 6,540 = ____________________

(5) 8,650,000 = ____________________

(6) 40,000 = ____________________

(7) 730,000 = ____________________

(8) 727,000,000 = ____________________

(9) 9,145,000 = ____________________

(10) 32,000,000 = ____________________

NAME ______________________________

Part III - Multiply the following numbers and express the answer in scientific notation. Show your work.

(1) 3.1×10^{3}
$\underline{5.8 \times 10^{5}}$

(2) 4.8×10^{11}
$\underline{6.1 \times 10^{2}}$

(3) 5.23×10^{7}
$\underline{3.6 \times 10^{3}}$

(4) 6.9×10^{5}
$\underline{4.7 \times 10^{1}}$

(5) 5.3×10^{4}
$\underline{3.5 \times 10^{5}}$

(6) 2.3×10^{6}
$\underline{4.1 \times 10^{4}}$

(7) 4.253×10^{4}
$\underline{1.5 \times 10^{2}}$

(8) 3.18×10^{6}
$\underline{2.1 \times 10^{2}}$

(9) 5.4×10^{5}
$\underline{1.7 \times 10^{8}}$

(10) 4.376×10^{5}
$\underline{3.5 \times 10^{4}}$

UNIVERSITY OF MARYLAND
BALTIMORE COUNTY

UMBC

5401 Wilkens Avenue · Baltimore, Maryland 21228

April 13, 1972

Mrs. Betty G. Carpenter
Ridgely Junior High School
121 Ridgely Road
Baltimore, Maryland 21093

Dear Mrs. Carpenter:

Last fall I promised that after you had returned the retention test on scientific notation to Dr. William Gray we would be able to disclose to you the purpose of the entire research project in which you participated. There has been a trend in school districts across the country to prepare teaching materials which include behavioral objectives. No research has been done to determine the difference in student achievement and retention when teachers are told the behavioral objective of a unit of study.

Dr. Gray and I felt that research should be conducted to determine if students benefit by teachers knowing precisely the behavioral objectives of a unit of study. In addition, we felt that data should be obtained to determine the benefit to students when teachers have available a learning hierarchy for a unit of study. Hence, we assigned each of you to one of three groups and asked you to teach a unit in seventh grade math, based upon information you were given during the session at UMBC.

Participants in Group I met on October 30, and were asked to prepare and teach a unit on the topic: scientific notation. Participants in Group II met on November 6, and were asked to prepare and teach a unit on a specific behavioral objective in scientific notation. Those of you who participated in Group III met on November 13, and were given the same behavioral objective that Group II received. In addition, Group III members received a learning hierarchy for reaching the behavioral objective, and were asked to follow the hierarchy during their instruction of the math unit.

Since the purpose of the research was to determine the benefit to the students when teachers are told behavioral objectives and learning hierarchies, we did not attempt to find out how you used the information. Dr. Gray and I will be processing the data this summer. No teacher's or student's name will be identified with any of the results. We have coded the data to reflect the type of information that was given, rather than to whom it was given.

Should you be interested in the results of the project, please give either of us a call in the early fall.

Again, we would like to express to you our sincerest appreciation for your willingness to participate in the project. We believe the findings of the research will be an important contribution to students and teachers throughout the country.

Very truly yours,

J. Marvin Cook

J. Marvin Cook, Ph.D.
Associate Professor of Education

jmc/dgp

August 30, 1972

Dr. Henry H. Walbesser, Director
Bureau of Educational Research and Field Service
College of Education
University of Maryland
College Park, Maryland 20742

Dear Dr. Walbesser:

This is a formal statement of our earlier agreement that you will review the final report of the research project entitled "Learning and Rate of Forgetting When Teachers are Informed of Behavioral Objectives." Our earlier agreement was that you would receive $75.00 for this review.

The project has been funded under grant OEG-3-71-0072, by the United States Office of Education/DHEW, and has been designated as project #0-C-028.

You will be notified before the report will be submitted to you. I cannot predict at this time what date that will be.

If you have any questions concerning this agreement, or the project, please contact me.

Sincerely yours,

J. Marvin Cook
Associate Professor of Education

jmc/dgp

August 30, 1972

Dr. Edwin Kurtz
University of Texas
Permanium Basin
Midland, Texas 79701

Dear Dr. Kurtz:

This is a formal statement of our earlier agreement that you will review the final report of the research project entitled "Learning and Rate of Forgetting When Teachers are Informed of Behavioral Objectives." Our earlier agreement was that you would receive $75.00 for this review.

The project has been funded under grant OEG-3-71-0072, by the United States Office of Education/DHEW, and has been designated as project #0-C-028.

You will be notified before the report will be submitted to you. I cannot predict at this time what date that will be.

If you have any questions concerning this agreement, or the project, please contact me.

Sincerely yours,

J. Marvin Cook
Associate Professor of Education

jmc/dgp